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THE VOLTAIC BATTERY.

A COURSE OF SIX LECTURES,

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(Concluded from page 174.)

LECTURE VI.—PRACTICAL APPLICATIONS OF GALVANISM.

I WILL proceed to another application of galvanic electricity—the electric light. I have already shown you, in various ways, that sparks can be produced. If we make the terminals of our battery to consist of charcoal, then we get the spark most beautifully exhibited. The light is intensely bright. If we have copper and silver, and so on, for the terminals, they give their own particular colours to the sparks; but when we employ charcoal we get a better light than we do from anything else—a light which, in fact, rivals the sun. You see wherever the two pieces of charcoal touch we get this intensely bright light. This has nothing to do with the combustion of the charcoal; the charcoal is not burning, for the light will take place in water just as well as in the air. [The carbon terminals were immersed in a glass bowl of water, and a brilliant light was produced beneath the surface of the liquid.] The use of this light under the water has been suggested for catching fish, but I do not know with what success; perhaps the fish are enabled by it to see the net, or are led to suspect some mischief. Mr. Ladd will show you this light on the screen. The current of electricity goes from one point to the other; we suppose that it passes from the positive pole to the negative pole; we have reason for supposing that, because we find an actual transference of particles from the positive to the negative. This is the positive pole magnified on the screen, and you see the melted globules which are passing from it. It is necessary to bring the poles together at first, in order to ignite them, and then the carbon points may be removed to some distance from one another, and still this luminous vapour from the carbon flows across from one to another. You see what a beautiful band there is of this blue light starting from the white ends; we should find that the carbon would gradually wear away from one pole, and that it would be deposited upon the other. Watch these brilliant globules which are falling upon this pole; I think there is scarcely anything possible to be conceived more beautiful than that intense light, and you may imagine what force is acting there when it is capable of melting the coke. We will show you the heat of this electric light; it is, I believe, the greatest terrestrial heat we can produce; we shall be able to see upon the screen immediately the melting of metals by means of it. This electric light, as you are aware, has been suggested for various purposes; we have employed it several times during the course of these lectures, and we have been able to magnify objects and to show you phenomena which you could not otherwise have seen. But the electric light does not succeed very well for lighting up buildings. This is due to the unsteadiness of the light, especially when produced from a galvanic battery. We have now silver melting in the electric light, and this beautiful colour on the screen is caused by the vapour of silver which is passing across the interval. You see how far the vapour of silver goes; it is this green band. Now think of the heat necessary to vaporise silver; it is so beautiful that we must have another metal.

I was saying that this is not a very good light for the practical purposes of lighting buildings, for the galvanic battery is not a very constant thing, and these charcoal points have always to be kept at about the same distance, but the positive pole wears away more rapidly than the negative, and the poles are always changing their distance. This last circumstance can be overcome pretty well by machinery, but the irregularities of the galvanic battery cannot be overcome. An attempt was made to introduce this for lighthouse purposes, and Professor Faraday worked long and lovingly in order to introduce this bright light for the benefit of the sailors about our shores. But the electric light can be produced in other ways than by the galvanic battery; we can get it by rotating magnets, and by that means, originally discovered by Faraday, we are able to produce the brilliant, steady electric lights now sending their rays across the sea at Dungeness, and at two or three other places in England and France.

Here is the light due to lithium; it is caused by the magnificent vapour of that metal. Mr. Ladd is able to separate these points far from one another, because the lithium vapour conducts the voltaic force. I suppose we must look at another metal in this way.

Here is thallium. This vapour gives a peculiar green light; there it is, pouring off from the metal. You see how it is being sent out from the one charcoal, and the vapour is being condensed and deposited on the other pole.

I am very sorry that the hour is going away so fast, but I must say a word or two on another application of the voltaic force. You know very well that we can carry it to any distance we please. Well, then, we may employ it to set fire to gunpowder, or gun-cotton, or anything else of the sort, at a distance. And it has been so employed for removing obstructions in mining operations, blasting rocks, and so on. I remember one of the finest sights I ever saw was the blowing down of some of the buildings of the Great Exhibition, opposite Queen's Gate. I was then considerably interested in gun-cotton. The gun-cotton was ignited by means of the voltaic force, and the masses of building slowly settled down before us, being undermined by the blast. I have put in my pocket some string gun-cotton. You know the Austrians tried to introduce it for the purposes of war. Here is some of the Austrian match-line, and I have had a piece of it wound round there. [A piece of match-line was ignited by a battery-spark.] By just simply putting the wires upon the compound, we can set off the gun-cotton, and instead of gun-cotton we might take anything else of the same character, such as these little fuses. I do not want to blow up a large quantity of gun-

powder before you, because the fumes of gunpowder are not very pleasant, but we will ignite one of these little fuses. [An Abel's fuse was ignited by a spark from a Grove's battery.] If that fuse had been in connection with a mass of gunpowder or gun-cotton, we could have torn anything to pieces by the explosion. Well, this galvanic power, then, can be employed for a number of the arts of peace, and the more the better. Unfortunately, we have to do also with the arts of war, because the time has not yet come when nations have learnt to love one another, or when we can refer to any man, in the words of our Poet Laureate—

"As one who sings the death of war."

These batteries are employed in war for fuses and other things, and the application is especially valuable for blowing up things at a distance, and for firing torpedoes laid in channels to protect the shore. If a ship comes across one of these, we can explode the torpedo from afar, and probably make a hole in the ship.

I have now spoken to you about some of the applications of this force. We saw originally that it was a chemical force, called chemical affinity, caused by the replacement of one metal by another. We saw how this force—which was strictly chemical, consisting in the preference of one thing for another, the preference of A to combine with B, instead of with C—was able to produce phenomena which we call voltaic, and how it was capable of transferring itself to a distance; we saw also how we are able to obtain polarisation, that is, a peculiar arrangement of molecules, and the production of light and heat; and we have traced how this voltaic force is able to produce decompositions, not only in the original cell at which it starts, but other decompositions in different parts of the circuit; we have traced, too, how innumerable are the different combinations of metals, and acids, and salts which we may employ to produce this force; and how, in fact, there have been invented a very large number of batteries, each supposed to have some peculiar advantage; and during these last two lectures, or, rather, the last lecture and a half, I have endeavoured to bring before you some of the most important practical applications of this force. But before we part, I must just lead you to think how constantly this chemical force must be acting. We have it all over the world. In fact, almost all things, if they are in a wet condition, are acting upon one another. Wherever this is taking place, at any rate with three elements, we have the possibility of producing secondary chemical decompositions, and this must be constantly taking place upon the surface of the earth. You are aware, of course, that we frequently find metals in lodes in a crystalline form. We find these natural crystals assuming forms such as I showed you upon the screen artificially. Here are some specimens of silver and copper, looking very much like what may be artificially produced. Professor Tennant has kindly brought here some native copper and agates, and other things, in which we find also arborescent forms; and there is no doubt that in the formation of these minerals this chemical or voltaic force was exerted. I was at Penmaenmawr during the summer, and I got some of these specimens showing how in the slaty cleavage there this oxide of manganese assumed forms like those which we produced artificially here. In animals and plants we have this force also. I am sorry that I cannot dwell for any length of time upon this matter; but I must just show you a concluding experiment, perhaps two. The voltaic force which is produced in plants or animals is exceedingly feeble, and in order to show that there is really a galvanic battery in a plant or an animal, we must employ most delicate arrangements. With many plants, the succulent plants especially, we find that between one part and another this action is produced; and at the last Friday evening meeting in this institution it was shown by Dr. Sanderson that in the closing of Venus's Fly Trap there was a galvanic discharge. That plant has a leaf something like this—(two hands joined at the wrist, but with the palms separated, and the fingers spread)—and when the fly goes into it, it closes over the fly, and then squeezes out its juice. The fact of the galvanic current was shown us in this theatre. I have not got any of these carnivorous plants. If we take the muscles of recently killed animals we find that there is a current flowing from the inside of the muscle to the exterior part. It would be very easy to show you that my own body might form the liquid portion of a galvanic cell; but if we can show you the current in the muscle itself, then we should be showing you that which is much better. [A piece of animal muscle was placed in connection with the galvanometer.] There, our needle is swinging. It will come to rest gradually at somewhere about this point. Now you see an indication of the galvanic current in the muscle passing between the inside and the outside.

I have not been able to teach you much during these lectures. Of course, one cannot do that in six hours, but what I hope I have succeeded to a certain extent in doing is to give you an impulse to enquire further into these matters, and to make experiments for yourselves, and I do hope that you will all be students, more or less, of natural science. It is the pure study of the works of God, and, depend upon it, it will have a great effect upon your minds in enabling you to investigate truth. We are here brought right face to face with facts, and we can test our conclusions; and this does not unfit us, but, I think, fits us all the more for investigating what is true in other and, perhaps, more important branches of knowledge. Thus, I hope, you will all carry out these enquiries, and pursue these thoughts somewhat for yourselves, and if you have not much opportunity of experimenting, at any rate, read and keep your eyes open to what you may see in the rocks round about you, or other natural objects, or in the various arts of life. Let us think about the knowledge we possess, and the little observations we make, if they are true, may lead us up to the most important results, just as the little dancing of the frog's legs which Galvani observed led the way to the electric telegraph, which has extended its benefits over all the world.

I must now bring these lectures to a close. I thank you for your attention, and I hope you have had as much pleasure in listening to what I have said as I have had in speaking.

THE "SUSSEX FORTNIGHT."

The "Sussex Fortnight," as the racing period commencing with Goodwood and ending with Lewes is called,

has been of quite exceptional brilliance this year. The weather set in fine just as people were hesitating whether they would pack up for the outing which marks the close of the London season; and circumstances, generally, pointed to the probability of a very successful campaign for the lovers of the sport. Hence, the lawn and stands at Goodwood were never more numerously or brilliantly filled; better racing has seldom been witnessed in the grand old ducal park; and seldom have the general public fared so well as they did over the principal events at Goodwood, Brighton, and Lewes.

But it is not with the company, or the racing, or even with the luck of the public on these occasions that we have to do, so much as with the special telegraphic arrangements they called forth at various points in what is known as the Southern Division of the postal system. Goodwood, as many telegraphists will remember, was at no very remote period, altogether beyond the sphere of telegraphic operations. In the days of the companies the telegraph only existed at the railway station at Chichester, between which and the Grand Stand, some five miles distant, messages were conveyed by mounted messengers, at a fabulous cost both of time and money. We need hardly say that the messages were few in those days, although, few as they were, they brought in a goodly revenue by reason of the exceptionally high rates charged for their collection and transmission. In 1870 the telegraphs were transferred to the Government, and in that and the following year the business arising in connection with the Goodwood meeting was conducted at the Post Office at Chichester, where—owing to the reduction of the charge, and the increased facilities—it assumed much greater proportions than at the railway station, although it was still sadly crippled by a cumbrous and expensive messenger service. About 3,000 messages in 1870, and 4,000 in 1871, comprised the business transacted at Chichester during the Goodwood week; and perhaps the number is as large as could reasonably have been expected under the circumstances. But clearly the meeting was worth a great deal more, especially when compared with other meetings of less importance, in connection with which a wire or wires had been carried to the Grand Stand; and the Post Office was not long in suing for permission to carry its wires to the top of the Sussex Downs. Anyone who has visited Goodwood can easily understand the objection which the Duke of Richmond naturally and properly entertained against any proposition to erect poles and wires through one of the most picturesque and beautiful parks in England. An underground line would have been much too costly, especially as it would only be brought into use during a single week in the year; and it was left to the Post Office to solve the difficulty which had sorely puzzled the Telegraph Company. A flying cable very soon suggested itself; and to this project, which was carried out for the first time in 1872, the Duke of Richmond not only offered no objection, but afforded the Post Office every facility for laying out the cable, and afterwards recovering it. The cable is composed of four wires firmly bound together, and taped and tarred in the usual manner. It is about half-an-inch in diameter, or perhaps rather more, is laid out in half-mile sections, or thereabouts, and covers a total distance of nearly five miles. Starting from the main line of wires near the Drayton Station of the South Coast Railway, it threads its way—now on the top of a hedge, now at the bottom of a ditch, now under and now over the roadway, until it reaches the confines of Goodwark Park, whence it is carried among the shrubbery and through the trees to the Grand Stand. We have said that this cable was brought into use for the first time in 1872—in that and the following year it was worked from the travelling telegraph office, stationed at the Grand Stand; and on the first occasion the business of the meeting exactly doubled itself, while in 1873, the number of messages had reached 9,000, or three times as many as were disposed of at Chichester in 1870. But four circuits worked in the ordinary manner soon became inadequate for the increase of business which developed itself, immediately communication with the Grand Stand was opened up; and as there were only four wires in the cable, the adoption of Wheatstone working became inevitable. The travelling office, however, was not adapted for any extensive application of this system: and had not the Duke of Richmond supplemented his concession about the wires by a still more liberal concession in respect of an office, the development of traffic which so speedily manifested itself must have been nipped in the bud so to speak. Last year a new and commodious office, having access on three sides to the private stand, the paddock, and the public enclosure, was occupied by the Post Office; Wheatstone apparatus was brought into use on each of the four wires of the cable; and both London and Manchester were placed *en rapport* with the Sussex Downs. A most satisfactory increase of business resulted, and it was thought that the work could hardly go on increasing in the same ratio as it had done since the extension of the wires in 1872. How mistaken was this notion may be gathered from the fact that between Chichester and the Grand Stand no fewer than 13,000 messages were forwarded and received during the four days of the recent meeting, and that on a single day nearly as many messages were disposed of at the Grand Stand alone as were dealt with at Chichester during the whole meeting of 1870! Some of our readers will be able to form an idea of what working four Wheatstone circuits at full speed means, altho' the sight is hardly to be witnessed in any office out of London—but few will receive, without a certain amount of incredulity, the statement that upwards of 400 messages were received in a single batch at Goodwood without stopping, except for "paper." An average of 800 messages a-day were received for delivery at the Grand Stand, and the public enclosure was literally strewn with opened envelopes at the termination of the meeting. London, Manchester, and Newcastle were all "spoken" direct from Goodwood; press messages, of which some 1,500 were handed in for transmission during the meeting, were sent simultaneously to the two first-mentioned places, and Newcastle was "put through" in the evenings for the sporting messages, which are usually sent to the newspapers in that town. In fact, Goodwood was, for the time being, a telegraph centre of scarcely less importance than Bristol or Birmingham, and it possessed as far stretching range of communication as either of these busy centres. But within a day or so after conclusion of the meeting, the cable had been removed, and the Sussex Downs were freed once more from the trammels of civilisation for another year.

Many people wonder that the cable has never been cut, and so it is subject matter for surprise. But the arrangements for laying out and watching are very complete, and nothing worse than a cow has interfered with them. A member of this interesting species placed herself "intermediate" on the cable, by taking a bite out of it, on the day before the race meeting commenced; and thus recalled Stephenson's celebrated joke about the "coo" and the locomotive. But the "fault" was speedily detected, and as the bite could hardly have been a very savoury one, the same cow is not likely to offend again. A good deal of ingenuity is developed by the working out of such arrangements as those at Goodwood, which we have only very imperfectly described. At the recent meeting a Wheatstone weight was found wanting at the supreme moment, when the starting of a fourth transmitter was indispensable to the saving of the business from collapse. There was not even a grocer's shop within five miles at which a 56lb. weight could be borrowed, and matters threatened to turn out serious. Happy thought! A working battery is about the proper weight, and one of these attached to the chain, and hoisted into mid-air, like a veritable Mahomet's coffin, did double duty on the same circuit

during the whole of the meeting. The idea was singularly happy; for it has been one of the greatest inconveniences of the special staff, to transport the Wheatstone weights to the numerous small offices at which it has become necessary to introduce that instrument on special occasions. There is always a battery at every office, whether there is a grocer's shop in the town or not. This little circumstance, together with the rigging up of punching desks under a "spreading chestnut tree," in the postmaster's garden at Chichester, combined to impart interest and variety to a week of almost unexampled hard work at a race meeting.

We have been so interested in the arrangements at Goodwood, that we have left ourselves little space to speak of those at Brighton and Lewes. Suffice it to say, that they were not particularly striking, unless in so far as they led to an enormous increase of business at both places. The two wires at the grand stand in each case, which a year or two ago proved ample for the requirements of the respective meetings, were raised to the capacity of four by the exclusive use of the Wheatstone apparatus; and the so-called permanent offices were supplemented by a tent, in which, mounted on empty orange-boxes, or any kind of "fitting" which came handiest, the staff disposed of some 1,000 or 1,200 messages a day at each of the meetings. Altogether, the two meetings produced a total of 12,000 messages between them, as compared with 8,000 last year, and with 9,000 in 1873. We need hardly say that the effect on the telegraphic business of the district created by the annual recurrence of the "Sussex fortnight" is very much greater than can be readily inferred from the figures we have quoted above. Not only at Goodwood and Chichester, but at Bognor, Brighton, Worthing, and Southsea, as well as in the Isle of Wight, a large increase of business takes place; and it is estimated that not fewer than 29,000 telegrams must be credited to the three Sussex race gatherings. And just as Goodwood is held to mark the close of the London season, so it may be said to mark the height of the telegraphic season; for we learn that during the Goodwood week the highest number of messages on record—viz., 232,400—passed the central station, and that on two successive days of the week the numbers touched 40,000!

GRAMME'S MAGNETO-ELECTRIC MACHINES.

By ALFRED NIAUDET-BREQUET.

M. GRAMME recently addressed to the Academy of Sciences a third communication respecting improvements in his magneto-electric machine. These improvements are so very remarkable that they cannot fail to be of interest to readers of the *Telegraphic Journal*.*

The *Revue Industrielle* and the *Chronique de l'Industrie* have already repeatedly referred to the admirable invention of magneto-electric continuous-current machines; but the modifications recently introduced by M. Gramme are so original and so important that they constitute in themselves a work able, so to speak, to revolutionise a host of industries. We therefore give this subject prominent notice, although we may recapitulate what has already appeared in our columns.

The discovery of magneto-electric induction currents by Faraday, in 1832, opened a new field of study to physicists and inventors. Pixii, maker of scientific instruments at Paris, was the first to construct an instrument furnishing practical induction currents; his apparatus, successively improved by Saxton, Clarke, Wheatstone, Wilde, Siemens, and Ladd, has bestowed immense service upon science and industry. Singularly, this invention of Pixii is best known by the name of Clarke's machine, although Clarke, of all the persons just mentioned, introduced the least important improvement. The Nollet machine, generally known as the *Alliance*, is but a particular arrangement of a group of Clarke's instruments.

Gramme's machine is not, however, a more or less fortunate modification of Pixii's apparatus; it is the first of its kind, as the following explanation will clearly show.

PRINCIPLE OF THE MACHINE.

To understand its principle it will be advisable to describe the most simple magneto-electric induction experiment which it is possible to make.

Contemplate a magnetic bar A B (Fig. 1) one metre long, and a spiral of conducting wire, in reciprocal movement. If the helix, starting from the position X, is made to approach the bar, an induced current is set up in the helix. Such is the sum and substance of the phenomenon, and there explanations as a rule stop; but let us proceed further and examine more closely what is the result in proportion as the bar enters into the helix by a series of successive and equally spaced movements—5 centimetres for example.

It will be observed that an induced current corresponds to each of these movements, and that these currents are in the same direction until the helix surrounds the neutral line M of the bar A B; and that the currents are in the opposite direction if the movement continues beyond that line.

Thus in the entire course of the helix over the magnet two definite periods are observed; in the first half of the movement the currents are *direct*, in the second they are *inverse*.

If, in place of motion from left to right, the movement is effected from right to left, the results

FIG. 1.

are the same, but the currents are in opposite directions.

Let us now investigate a more complex case still represented by figure 1. Two magnets, A B and B' A', are placed end to end, in contact by poles of similar names, B and B'. The whole becomes a single magnet with a consequent point in the middle.

If the spiral is moved in accordance with this

* Several articles and abstracts from *Comptes Rendus*, &c., on Gramme's machines, have from time to time appeared in our pages.—Ed. T. J.

system, it is clearly seen from the preceding explanation that it is traversed by a positive current during the first quarter of its movement (between A and M); by a negative current in the second quarter (from M to B); again by a negative current in the third quarter (from B^1 to M^1); and lastly by a positive current during the last quarter of the bar (from M^1 to A^1). It will be seen hereafter how this very simple explanation gives the key to the production of currents in the machines about to be described.

Description of the Apparatus.

The essential portion of the machine is the "ring" (Fig. 2), which turns around its centre between the poles of a magnet. It is an electro magnet of particular form. It may be conceived as a straight electro-magnet, bent into a circle and soldered together at its extremities, iron with iron, and wire with wire.

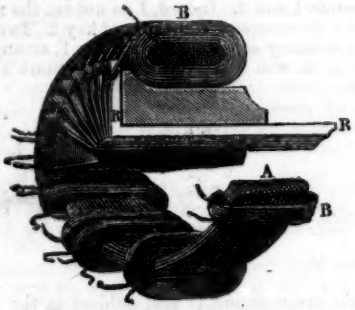


Fig. 2.

The wire is distributed upon the "ring" as in straight electro-magnets, notably those of powerful induction coils. It is rolled into distinct bobbins, which are then placed side by side, as shown in Fig. 2. These coils constitute the elements of the machine, just as voltaic couples form the elements of a voltaic battery. To render its construction intelligible, the engraving represents the "ring" complete in one part only; in another part the coils are figured by ones or twos; and in another portion the iron ring is exposed bare and cut.

This ring of soft iron is magnetised by the magnet N S (Fig 3), and the magnetism becomes distributed in the following manner. At B and A are the poles, whilst at M and M^1 (at right angles to the poles) are the neutral points. During the movement of the ring, this distribution of magnetism does not change, or at least it is invariable in position on account of the want of coercive force in soft iron. Hence, the result of turning the soft iron ring is just as if the circular iron upon which the coils are mounted was stationary, and as if these helices alone moved upon a magnetic bar.

The ring may be considered as composed of two magnets B A and A B joined by their poles of similar names. If any particular coil is followed in its movement throughout the complete circle it will be observed by referring back to fig. 1, and to the explanations already given that the developed current remains of the same character during the time the coil passes from A to M; it becomes *inverse* from M to B and from B to M^1; again changing to *direct* from M^1 to A.*

In other words, the current set up in a coil continues in the same direction from one neutral point to the other; if it is direct above that line, it is indirect below it. The line MM^1 may be called the *line of division*, and it is perpendicular to the line of the exciting magnet's pole NS. The line of division in Clarke's machine is that of the magnet's poles.

* To thoroughly understand that the direction of the current from B to M^1 is the same as from M to A, the simplest plan is to remember that the current from A to M^1 is contrary to that from B to M. This is easily perceived by again referring to "Principal of the Machine," for it is only saying that (Fig. 1) if the helix goes first from M to A and afterwards from BB^1 to M^1, the two currents thus induced are of opposite characters.

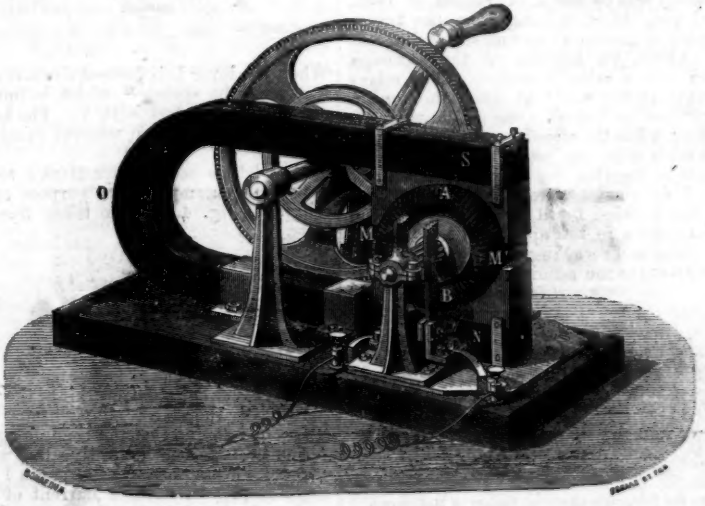


Fig 3.

Therefore we perceive, in supposing the ring to be composed of 60 coils, that the 30 coils which, at a given moment, are in the upper half-circle, are at the same time traversed by positive currents; whilst the 30 coils in the lower half of the ring are the seats of negative currents. The total current of the upper is equal to that of the lower, and the complete machine is, in all respects, comparable to a system of two batteries of 30 elements each, joined up in opposition.

Now to make use of such a system we have merely to join up the two extremities of a circuit to the ordinary poles of the two batteries when the currents are no longer in opposition, but joined up for quantity.

After this fashion M. Gramme collects the currents induced in the ring of his machine. He fixes on the line of neutral points collectors formed of copper pencils, which rub against the system of radiating pieces R (fig. 2) metallically in communication with the coils' conducting wires.

This arrangement is so novel as to require to be more fully explained. Figure 2 shows the different coils or elements of the ring and the radiating pieces R, insulated from each other, but each connected to the *exit* end of one coil, and to the *ingress* end of the following coil. These insulated pieces are bent back at right angles to the axis of the ring and are continued beyond the interior of the ring. In the complete drawing (fig 3) their extremities are noticed to be brought together into the form of a small cylinder, but insulated by burs of silk, or any other insulating material. At the same time may be seen the brushes which rub against the pieces R in a plane perpendicular to the line of the poles, *i.e.*, to the middle or neutral points M and M'.

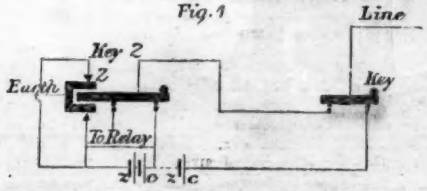
ON THE TRANSMISSION OF TWO MESSAGES IN THE SAME DIRECTION AT THE SAME TIME ON ONE WIRE.

By Mr. D. J. McGAURAN.

According to Sabine, "The first success obtained in this direction was by Stark, of Vienna, in 1855. His method consists of sending from the transmitting station by two keys two currents of different intensities, which, on arriving at the receiving station, each sets a relay in motion. The relays are arranged in such a way that when the weaker currents traverse the line only one of the relays is put in motion; when the stronger current traverses the line the other relay is affected; and lastly, when both currents go together, both the relays respond to them." I do not know to what extent Stark succeeded, but I think I will be able to show you some serious defects in the apparatus he devised, both for sending and receiving.

First, he arranges the sending keys as in Fig. 1.

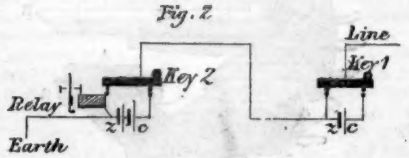
Fig. 1



* Read before the Telegraph Electrical Society of Melbourne, February 10th, 1875.

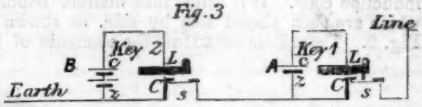
For this diagram I am indebted to Sabine. The objects attained are, that when one key is pressed down a current of a certain strength is sent, when the other key is pressed down a current of twice that strength is sent, and when both keys are pressed down a current is sent equal to both those currents combined, that is, a current of three times the strength of the current first mentioned. This proportion of the currents is not exactly true, but it is sufficiently nearly so for practical purposes. No provision is made in Stark's system for the break that takes place when, in the act of pressing either of the keys down, the lever is not resting on either the front or the back contacts. For instance, if we imagine key 2 to be closed, and transmitting a current to the distant station, the act of closing or opening key 1 will open the circuit for an instant, thus breaking the signal being transmitted by key 2. A similar effect takes place when key 2 is opened or closed while key 1 is closed, caused by the movement of the earth contact piece between the points 1 and 2. Indeed, I do not see the necessity for the complicated nature of key 2. Two keys of the ordinary construction like key 1, arranged as in Fig. 2, will accomplish all that Stark's keys effect.

Fig. 2



This arrangement is still subject to the defect before mentioned, the break caused by the opening or closing of the keys; we can get rid of this by the employment of 2 keys constructed as in Fig. 3.

Fig. 3



When the lever L is pressed down it comes in contact with the spring S, which is immediately removed from contact with C. The battery A or B is thus put into circuit without causing any interruption.

Now let us see how far Stark's receiving apparatus will accomplish the purpose required. The diagram (Fig. 4.) is also taken from Sabine, but

Fig. 4

the local circuits for working the sounders are omitted for the sake of simplicity.

Let us imagine that the sending apparatus performs its functions perfectly—that when key 1 is pressed down a current of strength 1 is sent, when key 2 is pressed down a current of strength 2 is sent, and when both keys are pressed down at the

same time a current of strength 3 is sent. Relay 1 is adjusted so that it is moved by current 1. Relay 2 is adjusted higher, so that it requires current 2 to move it. When relay 2 moves it closes the circuit of a local battery through a coil of wire wound round the relay 1 in such a manner that the current from it neutralises the effect which current 2 would otherwise have on relay 1. A resistance coil, R, is placed in this counteracting circuit, so as to adjust the current to the proper strength. Current 3 moves both relays, because the counteracting current is only equal to current 2.

You will notice, however, that when current 2 is received, before the tongue of relay 2 can close the circuit of the counteracting battery, it has to travel from the back to the front contact, and, no matter how small a distance this may be, it takes time; moreover, relay 1 being adjusted lower moves more quickly and reaches the front stop first. The consequence is, that relay 1 closes the circuit of its sounder before the counteracting battery is put on to stop it. The result is, when key 1 alone is worked, relay 1 works all right, and relay 2 is silent; when key 2 is worked alone, relay 2 works all right, but relay 1 makes a dot every time key 2 is closed. The effect of this would be that, when both keys were forming signals, the signals made by relay 1 would be irregular and untrue, dots being made when they should not occur, &c.

The following extract from the *Telegraphic Journal*, of November 15th, 1874, will show you that the subject has been engaging attention elsewhere lately:—

"Duplex telegraphy having now been established as a system, and its great value under certain conditions having come to be generally recognised, we are not surprised to find that, in more than one quarter, efforts are being made to utilise the discovery made in 1855 by Dr. Stark, of Vienna, of sending two messages simultaneously along a wire in the same direction, and to introduce, based upon that, a system of Quadruplex Telegraphy. The American *Journal of the Telegraph* states that between New York and Boston 402 messages taken at random from the current business of the day were sent over a single wire 300 miles in one hour and a half. Four operators were employed in sending, and four in receiving. The messages were of average length, and fairly represented the ordinary correspondence of the lines. The operators were all first class, and worked as fast as they could, one of them receiving 90 messages in an hour."

If this be true, which there is no reason to doubt, the defects which I have pointed out in Stark's method must have been removed, or some new method invented. As no account of the apparatus has reached us yet, I am unable to say how the result is obtained. I have been devoting a little attention to the subject myself, but up to the present time I have not succeeded entirely to my satisfaction. It is the arrangement of the receiving apparatus that presents the greatest difficulty, the sending apparatus being comparatively simple.

There are two distinct methods by which the variation of the strength of the currents can be effected. The first is variation of the battery power; the second, variation of the resistance of the whole circuit. Increasing the resistance of course diminishes the current, and *vice versa*. Either of these methods can be used according to circumstances, but the first one is the most applicable to be used in conjunction with the *so-called* duplex system to produce the quadruplex system, and I have no doubt that the method referred to in the extract which I have just read will be found to depend on the variation of the battery power.

There are a great many modifications of both these methods. For instance, by either we can send currents varying in strength 1, 2, or 3, by one or other or both keys being pressed down; we can, by the first, send a positive current by one key, a negative current by the other, while both keys being pressed down at the same time will send a positive or negative current of twice the strength. By the second, we can vary the currents in almost any proportion we desire, according to the resistances employed.

It is by the second method that I would propose to meet the requirements of a special case which occurs in this colony. I refer to the Victorian Racing Club meetings, upon which occasions there is a large amount of business to be transmitted in one direction.

I will now describe the apparatus, which so far as I have experimented gives promise of the best result. For this particular case at the sending station (Fig. 5) there are two keys, one, key 2, of the ordinary construction, the other, key 1, being so arranged that when the lever L makes contact with the spring S it removes S from contact with P. A relay B controlling a local circuit is also placed at the sending end in case either of the receiving operators find it necessary to break. At the receiving station are shown three relays adjusted to work at different strengths of current, a key 3 for breaking, and also a main battery for supplying the current. If the line is not well insulated it would be better to place the main battery at the sending end, say, somewhere between the points A and C. However, in this particular case I anticipate no difficulty from that cause.

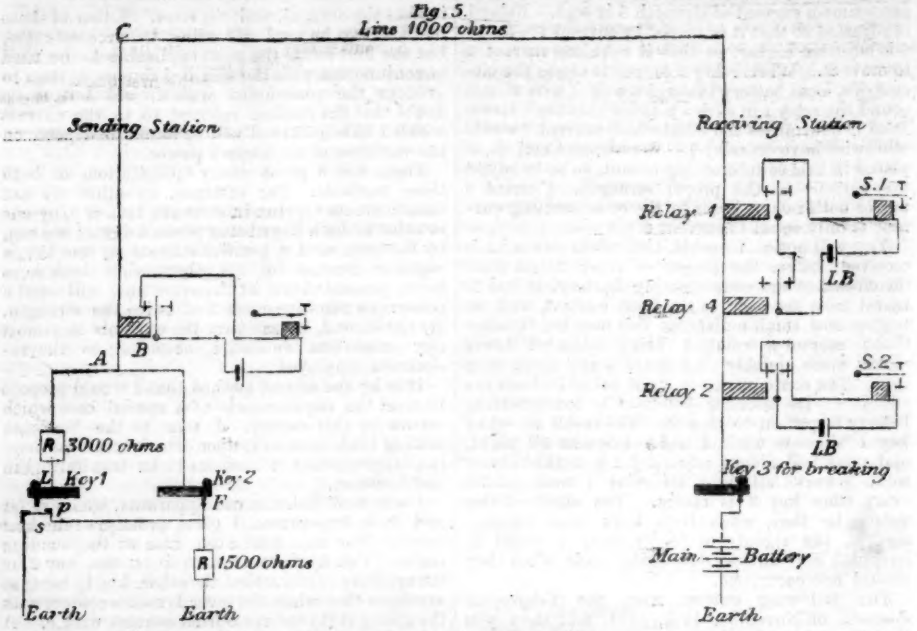
Now, let the resistance of all—apparatus, line, relays, and battery from the point A at the sending end, to the ground at the receiving end—be 1,000 ohms. Place 3,000 ohms between points A and L; place 1,500 ohms between the front stop F, of key 2, and the ground.

If key 1 is pressed down alone, the total resistance in circuit is $1,000 + 3,000 = 4,000$. If key 2 is pressed down alone, the total resistance is only 1,000, as the current has now a short circuit from A through key 2, and P S of key 1, to the ground. If both keys are pressed down at the same time, the connection between P and S is broken, and the resistance from A to the ground is now the joint resistance of 3,000 and 1,500, which is:—

$$= \frac{3,000 \times 1,500}{3,000 + 1,500} = \frac{4,500,000}{4,500} = 1,000$$

and the resistance of the whole circuit is 2,000. Therefore, when key 1 is pressed down, total resistance $= 4,000$; when key 2 is pressed down, total resistance $= 1,000$; and when both keys are pressed down, total resistance $= 2,000$; when key 1 is down, let the strength of current $= 1$; as the currents are inversely proportioned to the resistance; when key 2 is down the current is $= 4$; and when

Fig. 5.



both keys are down at the same time, the current = 2.

With these keys, then, we have perfect control over the strength of the currents, and all that now remains to be done is to arrange the receiving relays, so that they will perform their duties properly.

Each relay is marked with a number corresponding to the strength of current with which it moves. For instance, relay 1 moves with current 1, relay 2 with current 2, and relay 4 with current 4. Of course relay 1 also moves with currents 2 and 4, and relay 2 also moves with current 4.

First let us imagine both keys to be untouched. The tongues of the relays will all be lying against their back-stops; press down key 1 alone, current 1 circulates through the circuit affecting relay 1, thus closing the local circuit through the sounder S 1. Observe that this circuit passes through the tongue and back contact of relay 4. Press down key 2 alone; current 4 circulates through the circuit, affecting all three relays, relay 2 closing its local circuit through the sounder S 2, but the movement of relay 4 prevents the local circuit of sounder S 1 from being closed. Press down both keys simultaneously: current 2 circulates through the circuit; relays 1 and 2 are affected; but relay 4 remains unmoved. Consequently both local circuits now work their respective sounders.

Now, suppose while key 1 is down that key 2 is pressed down, the current is increased from 1 to 2, and relay 2 responds to the movement of key 2. If, while key 2 is down, and current 4 is circulating, key 1 is pressed down also, the current is diminished from 4 to 2, and the tongue of relay 4 closes the local circuit of the sounder S 1 by falling against the back contact. If operators are manipulating the two keys, the signals sent by key 2 are followed by the relay 2; but the signals of key 1 are followed by complicated motions of relays 1 and 4, the sounder S1 sometimes being moved by relay 1, and sometimes by relay 4. The sounder S 1 interprets, as it were, the otherwise unintelligible movements of these two relays.

I may mention that in practice I find it extremely difficult (at any rate with the relays that I have at my disposal) to regulate the adjustment so as to produce proper signals. The relays retain a considerable amount of magnetism after a current is passed through them. If current 4 is sent, relay 4 responds to it; but when this current is reduced to 2, the armature of relay 4 remains attracted instead of falling back as it ought to do. If the spring is tightened up so as to ensure the drawing of the armature back, then, if current 4 is sent, relay 1, moving more quickly, reaches the front stop before relay 4 leaves the back stop, thus causing a dot to be made on the sounder S 1.

Considerations of this sort induce me to believe that, unless relays of this construction can be procured that will work better, recourse must be had to relays constructed something like galvanometers, that is, without iron cores, and which would, of course, be free from this defect of residual magnetism. I hope to resume the subject before you at some future time, when I trust to be able to announce complete success in the matter.

Notes.

Oft-repeated wonders soon become commonplace matters. The *Faraday* which went out to the Coast of Newfoundland in April, to complete the laying of the Direct United States Cable, has just returned,

entered the Thames, taken in a stock of fresh cable, started on her return journey to complete her task, and no mention has been made of her in the morning papers! She had laid the cable, and it worked well, but there was a fault 250 miles off Newfoundland, which it was thought better to cut out, and she came home for more cable to enable her to do so.

It is narrated that certain Chinese fishermen brought up to the surface a submarine cable; that they cut it in small pieces, and planted it, hoping it would grow.

The traffic receipts of the Direct Spanish Telegraph Company for the month of July, 1875, were £1,834, against £1,349 in the corresponding period of last year.

The average time occupied in the transmission of telegrams between Madrid and England, "*via* Santander," was 3 hours and 9 minutes (including transmission over Spanish land lines).

An important case has been tried in the Vice-Admiralty Court of the Dominion of Canada, whereby the owners of a large timber ship, the *Czar*, have been condemned in costs and damages for injury done to a submarine cable crossing the river St. Lawrence, near Quebec, through the negligence of the persons in charge of her allowing her to drag her anchor over the cable.

Special events appear as prolific of telegraphic business in the United States as in England. Saratoga regatta produced 113,446 words of press matter, and 4,270 private messages. An office was opened at the Grand Stand, which was connected by a quadruplex with New York.

The Indiarubber, Gutta-percha, and Telegraph Works Company (Limited) have received news by telegraph of the successful laying and completion of their cable between Callao and Islay, in Peru. This section, about 460 miles in length, is the first of a series of cables, with stations at Arica and Iquique, in Peru, and Caldera in Chili, which will place those ports, as well as Lima and Valparaiso, in telegraphic communication with Europe—first by the Transandine wires and the Brazilian cable system, and ultimately by the Isthmus of Panama, when a cable shall have been laid thence to Callao.

Mr. Stearns has successfully introduced duplex working into France. The system he has inaugurated is capable of six combinations, viz., Morse single working, Hughes single working, Morse duplex, Hughes duplex, Morse-Hughes duplex, Hughes-Morse duplex. The bridge system is used, and the results upon the Hughes are very satisfactory, because it is found that the instruments work better duplexed than on the ordinary single method, from the fact that the outgoing currents do not pass through the home instruments, and therefore disturb them. Paris has been working to Havre uninterruptedly since the commencement of the year.

DECAY OF TIMBER.

THE following interesting description of a great enemy to all telegraphists is taken from a charming work by the Rev. Hugh MacMillian, on the "First Forms of Vegetation." Evidence of the presence of fungi is to be found in nearly every rotten pole, but whether the fungus is the cause or consequence of the decay is a vexed question. That it is so in some cases of *dry rot* is quite certain, but that it is so in *wet rot* is uncertain. Our readers—especially those who possess microscopes, that "new sense,"—would do good service to science if they would investigate every case of incipient decay with a view of solving this question.

"It is not only in food and luxuries that man suffers from the ravages of fungi; he also suffers in his property. Builders have painful knowledge of one or two species, known under the common name of dry-rot. This most destructive plague is usually caused in this country by the *merulius lachrymans*. It occurs on the inside of wainscoting, in the hollow trunks of trees, in the timber of ships, and in the floors and beams of buildings in moist, warm situations, where there is not a free circulation of air. It appears at first in round, white, cottony patches, from one to eight inches broad, which afterwards develope over their whole surface a number of fine yellow, orange, or reddish-brown irregular folds, most frequently so arranged as to have the appearance of pores, and distilling drops of moisture when perfect; whence its specific name. In the mature state it produces an immense number of minute rusty sporules, which alight and speedily vegetate in the circumjacent timber, destroying its elasticity and toughness, and rendering it incapable of resisting any pressure, until gradually it crumbles into dry brown dust. This insidious disease, once established, spreads with amazing rapidity, destroying some of the best and most solid-looking houses in a few years. The ships in the Crimea suffered more from this cause than from the ravages of fire, or the shot and shells of the enemy. The dry-rot of oak-built vessels is caused, however, not by the merulius but by the *polyporus hybridus*, whose mycelium forms a dense membrane of branched creeping strings, while the pores of the hymenium are long, slender and minute. So virulent is the nature of dry-rot that it extends from the woodwork of a house even to the walls themselves, and by penetrating their interstices, crumbles them into pieces. We have every reason to believe that the leprosy of houses, so graphically described in Leviticus, was a dry-rot caused by some species of merulius or polyporus; the materials and sanitary condition of Eastern houses being peculiarly favourable for the development and spread of fungous growth. "I knew," says Professor Burnett, "a house into which the rot gained admittance, and which, during the four years we rented it, had the parlours twice wainscoted, and

a new flight of stairs, the dry-rot having rendered it unsafe to go from the ground-floor to the bedrooms. Every precaution was taken to remove the decaying timbers when the new work was done; yet the dry-rot so rapidly gained strength that the house was ultimately pulled down. Some of my books which suffered least, and which I still retain, bear mournful impressions of its ruthless hand: others were so much affected that the leaves resembled tinder, and when the volumes were opened, fell out in dust or fragments.

Many practical persons have written upon this disease, and the remedies proposed are as numerous as their authors. But the only certain preventives of the evil seem to be the removal of the decaying and contagious matter, the kyanizing or impregnating of the surrounding wood with a strong solution of corrosive sublimate or coal-tar, and the admission of a free current of air. Much also may be done by cutting timber destined for building purposes in winter, when fungi are usually dormant or dead, and properly seasoning it by steeping it before it is used. Houses, in order to be free from this plague should be built in dry, open, and airy situations, and efficiently ventilated throughout every part, especially of the wood work. When these conditions are observed, this evil will disappear."

GATHERINGS FROM THE EDITOR'S NOTE BOOK.

Mr. Stuart Wortley, when Chairman of the Atlantic Telegraph Company, said that while they anticipated obtaining only 5 or 6 words per minute through the cable, they succeeded in getting, by means of Thomson's reflecting galvanometers, 15, and sometimes 20 words per minute.

Dr. W. H. Russell wrote in 1865:—

"But as a mite would in all probability never have been seen but for the invention of cheese, so it may be that there is some undeveloped creation waiting, *perdu*, for the first piece of gutta-percha, which comes down to arouse his faculty and fulfil his functions of life—a gutta-percha boring and eating *teredo*, who has been waiting for his meal since the beginning of the world." He may be ranked as a prophet, for the borer has appeared in the *limnoria terebraus*.

In order to try the porosity of pure gutta-percha, Macintosh, put upon the inner core some chemical substance, which upon contact with water changed colour. This was then covered with gutta-percha, and subjected to hydraulic pressure. Water in every case penetrated to the core under a pressure of 2 tons to the square inch.

Sir W. Thomson calls the British statute mile "that most meaningless of modern measures," and invariably means by mile the nautical mile, or the length of a minute of latitude in mean latitudes = 6,073 feet. For approximate measurement it may be taken as 6,000 feet or 1,000 fathoms. He calls the sea the very safest place in which a submarine cable can be kept, and asserts that sea water is the best preservative of gutta-percha. No case of decay of gutta-percha in water has ever been known.

The 1866 Atlantic Cable, when tested at the Gutta Percha Works, at 75° Fahr. gave a mean resistance of 374 ohms per knot (after 1 min. electrification) after being submerged the resistance of whole cable (1854 miles) was 1·316 ohms or 2437 ohms per knot. Temperature of water about 40° Fahr. Pressure at deepest point (about 2,400 fathoms) about 6,418 lbs. (nearly 3 tons) per square inch. Cable took 66 minutes to fall from charge to ½ charge. The resistance of copper conductor was 7202 ohms or 3·88 per knot.

Mr. Latimer Clark, telegraphed through both Atlantic Telegraph Cables with a battery formed in a lady's thimble, and Mr. Collett said, "I have just sent my compliments to Dr. Gould of Cambridge, who is at Valentia, with a battery composed of a gun cap with a strip of zinc excited by a drop of water, the simple bulk of a tear."

The following table may be regarded as a fair indication of the rate at which cables of the average inductive capacity can be worked with the mirror:

NUMBER OF WORDS PER MINUTE.

Weight of copper strands, lbs.	Knots, 1,000.	Knots, 1,500.	Knots, 2,000.	Knots, 2,500.
100	18·3	8·1	4·6	2·9
150	27·5	12·2	6·9	4·4
200	37·0	16·4	9·2	5·9
250	46·0	20·4	11·2	7·4
300	55·0	24·4	14·0	8·8
350	64·1	28·5	16·0	10·3
400	73·2	32·5	18·3	11·7

Cyrus Field said, when the 1865 cable failed, "Let us not despair, I have seen worse disasters than this in Atlantic telegraphy, and I know we must eventually succeed."

One man said, "I have put into the enterprise my all, but with God's blessing I shall live to see the Atlantic Cable laid. In spite of what has occurred, I am more than ever satisfied of the practicability of laying it."

When the Great Eastern arrived at Heart's Content "a blind girl, led by her young brother, walked about the deck, and gathered, from his intelligent description and by the exercise of her sense of touch, some notion of the great size of the ship. Coming up the ladder at the side gave her an idea of the height, and then a walk from stem to stern an estimate of the length. It was touching to see the radiant smile on this poor girl's face as she listened to the boy, who told her what wonders he saw."

Notices of Books.

Journal of the Society of Telegraph Engineers. London: F. & N. Spon.

The ninth number of this useful Journal has just been issued, and it is announced to be published quarterly for the future. Its appearance has hitherto been very fitful, and its regular publication will be a great improvement, for it is a most valuable periodical, and is very ably edited. We have full reports of the discussion upon Mr. Fabi's paper "On faults in Submarine Telegraph Cables," read on November 11th, 1874; upon Mr. Gavey's paper "On Earth-boring for Telegraph Poles,"

read November, 25th, 1874; and upon Lieut. Jekyll's paper "On the Telegraph and the Ashantee War," read December 9th, 1874.—There are interesting articles on telegraphic progress in 1874, Home, Foreign, and Colonial. Several valuable communications in other journals are reprinted, and there are two interesting papers on duplex telegraphy—the first from New Zealand, by Mr. C. Lemon, clear, precise, and practical; the other from India, by Mr. L. Schwendler, full of valuable information, but a burlesque on mathematical analysis. The tendency to put simple logical deductions into algebraic language and call it mathematics is very much on the increase. When this is done on false premises and any operation attempted upon it, the result is very likely to land the would-be mathematician in a quagmire. This is very nearly the case with this communication from India, in which the "general results" are not in accord with experience.

Transactions of the Telegraph Electrical Society of Melbourne.

We have received the second number of the transactions of this useful Society, which now numbers 120 members. It contains a paper by Mr. Geo. Smivert, on the "Origin of the Voltaic Current," favouring the contact theory; one by Mr. D. J. McGauran, "On the transmission of two messages in the same direction at the same time on one wire," which we reprint, and one on "Galvanic Batteries," by the same author, being part of a course of instruction about to be pursued in the Society. The Society is adopting a wise and profitable course, and we wish it every success.

Protection of Life and Property from Lightning during Thunderstorms, by W. McGregor. Bedford: W. J. Robinson.

This is an interesting little compilation, intended by its cheapness to make more public and general views and opinions which have been propounded to a limited circle in scientific books and before several scientific institutions. It is based on a short paper read by the author before the Bedfordshire Natural History Society on the 10th June, and it contains numerous extracts from the works of Dela Riv, Ganot, Snow Harris, &c., and from the papers of Dr. Mann and Mr. Preece. The cost is 1s., and we hope it will have an extensive circulation.

PNEUMATIC TELEGRAPHS FOR LONG DISTANCES.

Paper read at the meeting of the Society of Civil Engineers of Paris, on the 4th June, 1875.

By M. A. CRESPIN.

The pneumatic telegraph whose, origin dates from an already remote period, has during the last twenty years been in numerous cases brought into practical use, the first application of the system having been made in London by Latimer Clark. That city now possesses the most complete arrangement of the kind. The very important traffic of that great commercial centre requires arrangements of a special description, which have been carried out with the greatest success by the engineer-in-chief of the Post-office, Mr. Culley, and by Mr. Sabine.

After London, Berlin, Paris, and Vienna have successively adopted the new means of communication, and have laid down similar systems of tubes for the service of internal messages.

The favour which this new system, which cannot pretend to vie with electricity in point of capacity, has found is owing solely to the peculiar conditions which arise in the majority of great cities, that is to say, that the telegraph service is, in such cases, called upon to transmit a large number of messages over distances, comparatively, very short. Under such circumstances electricity is surpassed in speed by modes of transit whose action is much less instantaneous, but whose capacity for transmission is very much greater.

In order to render this rather abstract explanation more complete, I will take for example the case of a telegraphic wire having to transmit a certain number of messages over a distance of no more than one thousand metres, and I will compare with it a pneumatic tube performing a similar service. The wire will transmit the messages one by one, and it will not be able to send more than forty in an hour; a clerk must be employed at each end. By means of the tube the distance will be traversed in one minute, and a hundred messages can easily be carried; these messages can besides be the actual manuscripts, can be secret, and the apparatus being only affected by the bulk and weight of the messages, no matter how many words may be contained in the message, the transmission is equally rapid, and but two attendants are required. The case cited above is one in which the tube has a most incontestable advantage over the electric wire. It is easy to perceive that this advantage diminishes as the number of messages to be transmitted decreases, and it diminishes also as the distance which separates the two points increases. There arrives, therefore, a time when the wire regains the advantage; that is when it is able to transmit all the messages which have to be forwarded in a shorter time than it would take the tube to convey them over the same distance.

This method of collecting and distributing messages in great cities gives excellent results in all cases where the traffic is considerable. The arrangements established in the different cities vary according to the method of working, but the principle is always the same, and may be summed up as follows:—A tube, as perfectly round as possible, connects the two points which are to be placed in communication: one or more boxes (carriers) containing the messages are introduced into the tube by an apparatus, the essential features of which are always the same—that is to say, the tube is closed behind, and a branch tube opening into the main tube between the end of the latter and the train (boxes or carriers), directs a current of compressed air into the tube, producing a pressure H greater than the atmospheric pressure h, which acts at the other end. It is under the influence of this difference of pressure, $H-h$, that the train is driven forward along the line, continually receding from the point at which the compressed air is introduced.

When a message has to be brought in the reverse direction, the same point is placed in communication with a reservoir, in which the pressure is less than the atmospheric pressure h, which acts at the other end. $H-h$ is now negative, and the train placed at the extremity of the line is drawn back to the original point of departure, where it arrives at the end of a certain time. The suction of air is then stopped by the simple closing of a stop-cock,

and a door similar to that used for the sending allows the train to be taken out of the tube. An electrical communication is provided, by means of which the attendants, placed at the ends of the table, are able to control and direct all their operations.

The method employed for compressing the air and producing the vacuum may be any one of the methods by which this class of work can be performed. It appears, however, after different trials, that steam-engines, with direct-acting air-pumps, have been found to work with the greatest regularity, and have consequently been adopted almost universally in cities possessing pneumatic telegraphs.

As regards the circulation, this is effected either by a circular network, worked continuously or alternately, according to the importance of the traffic, or by a radiating system worked in the same manner. In both cases pressure is used for impelling the trains forward, and vacuum for drawing them inwards. The radiating system seems to have been established at the commencement, as being the most simple, and it has been maintained where the traffic is very important on account of its affording a service of the most direct character. The largest system of this kind is that of London, where special arrangements are made by which the tubes are traversed by continuous currents of air, into which the boxes or carriers to be forwarded are introduced by means of a species of sluice, the boxes received being taken out as they arrive by the same means. One of the first systems proposed for Paris, in 1860, by M. Antoine Kieffer, was arranged in a similar manner.

Pamphlet by M. Amédée Sebillot.—In 1866, when the first pneumatic lines were established in Paris, this system was not adopted, and the first works of the kind, executed in Paris by MM. Mignon and Rouart, were carried out upon the network principle, and worked by intermittent currents of messages at regular intervals, a mode of working which is more economical than the former, although rather less rapid.

After this short descriptive account, I come to the object of my paper. In the first place, I propose the following question:—

What are the laws which regulate approximately the movement of boxes in pneumatic tubes?

Experiment shows that the presence or absence of the train in a tube has but little influence upon the flow of the air, that the flow takes place under conditions almost identical with those which govern the flow of other fluids, and that the laws which are observed to prevail in the case of these other fluids can, without risk of too much error, be applied to the particular case now under consideration.

Let R be the resistance to the movement, l the length, X the perimeter, u the speed, a and b coefficients; the approximate formula for the flow of fluids is—

$$R = l X (au + bu^2)$$

Disregarding the term where the speed is in the first degree, the formula becomes—

$$R = b l X u^2$$

The force which causes the boxes to move being equal to the difference of pressure (H—h) multiplied by the section S upon which it is applied, the formula of the movement will be approximately—

$$(H-h) S = b l X u^2$$

which, in the case where the section is a circle, becomes—

$$H-h = \frac{8 b l u^2}{D} \quad \therefore \; u = A \sqrt{\frac{(H-h) D}{l}}$$

A formula which numerous experiments have shown to be sensibly correct for the conditions under which pneumatic tubes are usually established and worked, and which shows that the speed varies as the roots of all the conditions of the case, directly for pressure and diameter, universally for length.

As we are considering the means to be employed in order to construct a line of a length l, as great as possible, let us examine successively the influence of each of the forces or dimensions which affect the speed under these conditions.

The first thing to examine is certainly the pressure, or rather the difference of the moving pressure (H—h). The general formula shows that if we were to increase (H—h) and l in the same proportion, a constant speed would be obtained.

Unfortunately, this simple solution is an impossible one, for the practical means at our disposal do not allow of air being compressed at a sufficiently low cost; beyond a certain limit which is 1 effective atmosphere, or 2 atmospheres at most, the cost of compressing (owing to the great outlay necessary) is so considerable that if such a method of working were adopted, even supposing no obstacles were encountered from the elevation of the temperature and the moisture of the air, it would be impossible to organize a remunerative service. A limit would besides be quickly reached, for even by very costly processes, it is with the greatest difficulty that a pressure of from 5 to 6 atmospheres can be exceeded.

In the same way with vacuum. In continuous working a vacuum of much more than 0·50 metres of mercury cannot be depended upon. In conclusion, a pneumatic line arranged for economical working must not require a pressure of more than 2 atmospheres at most, nor a vacuum of more than 0·55 metres of mercury.

The second point to be examined is the diameter of the tube. Here it seems evident that no mechanical difficulty prevents a considerable increase, the formula shows that by increasing in the same proportion as the length, a constant speed will be obtained; experiment confirms this conclusion satisfactorily as regards the speed, and, in fact, the speed is generally found to exceed that shown by the formula. Unfortunately this plan would be too costly: it would result in the laying of very large tubes between points very far apart, even when the traffic between these points might be very small. Now, the cost of laying a pneumatic line increases very quickly with the diameter, much faster than the diameter, and the cost of working increases more quickly than the square of the diameter. It follows, from what has been previously stated, that, in laying a pneumatic line, the only point to be taken into consideration in fixing the diameter of the tube is the amount of the traffic to be conveyed by it, and we shall see further on, that to accommodate an important traffic, it is not necessary to exceed a section which, at first sight, appears extremely small.

(To be Continued